IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁏ Peer-reviewed & Refereed journal ⁏ Vol. 13, Issue 4, April 2026

DOI: 10.17148/IARJSET.2026.13405

DEVELOPMENT OF AN ADVANCED AUTOMATIC BRAKING SYSTEM USING MULTI ULTRASONIC SENSORS

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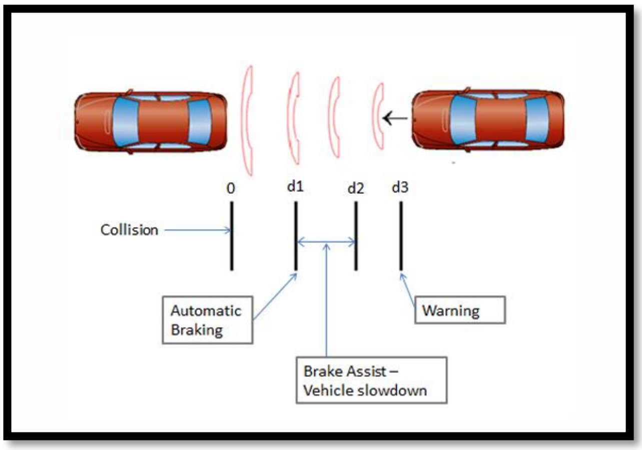
Abstract: The increasing demand for enhanced vehicular safety has driven the development of intelligent braking systems capable of minimizing human error and preventing accidents. This paper presents the design and development of an advanced automatic braking system utilizing multiple ultrasonic sensors for real-time obstacle detection and embedded control. The proposed system employs a multi-sensor configuration to improve detection accuracy and coverage by monitoring obstacles in multiple directions. An embedded microcontroller-based architecture is used to continuously process sensor data and evaluate the distance between the vehicle and surrounding objects. Based on predefined threshold conditions, the system performs dynamic decision-making to initiate appropriate actions, including warning generation, speed reduction, and automatic braking. A motor driver interface is implemented to regulate the motion of the vehicle, ensuring smooth and controlled braking performance. Additionally, a wireless communication module is integrated to enable remote monitoring and user interaction through a mobile device. The developed prototype demonstrates reliable performance in detecting obstacles and responding with minimal delay, thereby reducing the risk of collision. The system offers a cost-effective, efficient, and scalable solution for implementation in autonomous vehicles, robotic systems, and intelligent transportation applications. The results validate the effectiveness of the proposed approach in enhancing safety through real-time sensing and automated control mechanisms.

Index Terms: Automatic Braking System, Ultrasonic Sensors, Arduino Nano, Obstacle Detection, Embedded Systems, Collision Avoidance

I. INTRODUCTION

Road safety has become a major global concern due to the increasing number of vehicles and the growing incidence of accidents caused by human error. Conventional braking systems rely entirely on driver response, which may be delayed or insufficient in critical situations. Factors such as lack of attention, fatigue, and limited reaction time significantly contribute to collision risks. To address these challenges, the development of intelligent braking systems has gained considerable attention in recent years.



Automatic braking systems are designed to detect obstacles and apply braking without human intervention, thereby enhancing vehicle safety and reducing accident rates. These systems utilize sensors and embedded control mechanisms to continuously monitor the surroundings and make real-time decisions. Among various sensing technologies, ultrasonic sensors are widely used due to their simplicity, cost-effectiveness, and capability to measure distance accurately in short-

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range applications. In this work, an advanced automatic braking system based on multiple ultrasonic sensors is proposed. The system employs a multi-sensor configuration to improve obstacle detection coverage and minimize blind spots. An embedded microcontroller is used to process sensor data and evaluate the distance between the vehicle and obstacles in real time. Based on predefined threshold values, the system generates appropriate responses such as warning signals, speed reduction, and automatic braking.
The integration of a motor driver enables precise control of the vehicle's motion, ensuring smooth and efficient braking action. Additionally, a wireless communication module is incorporated to facilitate interaction with a mobile device for monitoring and control purposes. The overall system is designed to be compact, cost-effective, and suitable for real-time implementation in various applications. The proposed system demonstrates a practical approach to improving vehicle safety by combining real-time sensing, embedded processing, and automated control. It has potential applications in autonomous vehicles, robotic platforms, and intelligent transportation systems, where rapid response and reliability are critical for accident prevention.

II. LITERATURE REVIEW

Several research works have been carried out in the field of automatic braking systems to improve vehicle safety and reduce accidents caused by human error. These systems primarily focus on obstacle detection and real-time control using sensors and embedded technologies.

Devender Kumar J Pal et al. proposed an automatic braking system using ultrasonic sensors for obstacle detection. Their system utilized a microcontroller to process sensor data and control braking action based on the distance between the vehicle and obstacles. The study demonstrated that such systems can significantly reduce accidents caused by delayed human response.

Rutvik Lahane et al. developed an ultrasonic-based forward collision avoidance system that continuously monitors the distance between the vehicle and nearby objects. The system automatically applies braking when the distance becomes critical, highlighting the importance of real-time sensing and control in enhancing safety.

S. Sharanya et al. presented a microcontroller-based automatic braking system using ultrasonic sensors. Their approach included both warning and automatic stopping mechanisms, which effectively minimized collision risks and improved system responsiveness compared to traditional braking methods.

R. Sangeethkumar et al. discussed the evolution of braking systems from conventional mechanisms to advanced sensor-based technologies. Their work emphasized the integration of electronics and control systems to improve braking efficiency and reliability in modern vehicles.

Devireddy Naga Jyothi proposed an intelligent braking system that automatically adjusts vehicle speed based on obstacle distance. The study highlighted the role of automation in reducing driver dependency and improving safety in dynamic environments.

Gitanjali Mehta et al. introduced an IoT-based automatic braking and accident detection system. Their system incorporated wireless communication for real-time monitoring and emergency response, demonstrating the potential of integrating smart technologies with braking systems.

Despite these advancements, many existing systems are limited in detection coverage and adaptability. The proposed work addresses these limitations by using multiple ultrasonic sensors to enhance detection accuracy and integrating wireless communication for improved system interaction and monitoring.

III. METHODOLOGY

The proposed advanced automatic braking system is designed based on real-time sensing, data processing, and automated control. The methodology integrates multiple ultrasonic sensors, an embedded microcontroller, and a motor control unit to detect obstacles and apply braking without human intervention. The system follows a structured approach to ensure accurate detection, quick response, and reliable operation.

System Architecture
The system consists of three major functional stages:
- **Sensing Stage** → Detection of obstacles using multiple ultrasonic sensors
- **Processing Stage** → Data analysis using a microcontroller

DOI: 10.17148/IARJSET.2026.13405

- **Actuation Stage** → Motor control and braking mechanism

This layered architecture ensures efficient coordination between hardware and software components.

Obstacle Detection Mechanism

Three ultrasonic sensors are deployed at the front of the vehicle to detect obstacles in multiple directions. These sensors continuously emit ultrasonic waves and receive reflected signals from nearby objects. The time delay between transmission and reception is used to calculate the distance between the vehicle and obstacles.
The use of multiple sensors improves detection coverage and reduces blind spots, enhancing the reliability of the system in real-time environments.

Data Acquisition and Processing

The microcontroller serves as the central processing unit, continuously collecting distance data from all sensors. The acquired data is processed in real time to evaluate the proximity of obstacles. Distance values are computed using ultrasonic sensing principles, and the system continuously updates these values to ensure accurate monitoring.

Decision-Making Strategy

The system employs a threshold-based decision-making algorithm to determine appropriate actions. Based on the measured distance, the system operates in different modes:

- **Safe Condition** → Normal operation
- **Warning Condition** → Activation of alert system
- **Critical Condition** → Reduction of motor speed
- **Emergency Condition** → Complete stopping of the vehicle

This multi-level control strategy ensures gradual braking and prevents sudden system responses.

Braking Control Mechanism

The motor driver module receives control signals from the microcontroller and regulates the speed of the DC motors. Depending on the detected distance, the system adjusts motor operation to simulate braking. This approach provides smooth deceleration and ensures stability during operation.

Wireless Communication

A Bluetooth module is integrated into the system to enable communication with a mobile device. This feature allows monitoring of system status and provides an interface for optional control, enhancing user interaction and system flexibility.

Power Management

The system is powered by a battery, and a voltage regulation unit is used to provide stable power to all components. Proper power management ensures efficient operation and protects the system from voltage fluctuations.

Algorithm

The overall operation of the system follows these steps:

1. Initialize all components
2. Acquire distance data from ultrasonic sensors
3. Process sensor data in real time
4. Compare values with predefined thresholds
5. Generate warning signals if required
6. Adjust motor speed based on conditions
7. Apply automatic braking when necessary
8. Repeat continuously

The proposed methodology combines multi-sensor detection, embedded processing, and automated control to achieve an efficient automatic braking system. The structured approach ensures accurate obstacle detection, rapid response, and reliable system performance, making it suitable for real-time safety applications

IV. DESIGN AND IMPLEMENTATION

1. System Design Overview

The design of the proposed automatic braking system is based on the integration of sensing, processing, and actuation modules to achieve real-time obstacle detection and braking control. The system adopts a modular architecture consisting

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 4, April 2026

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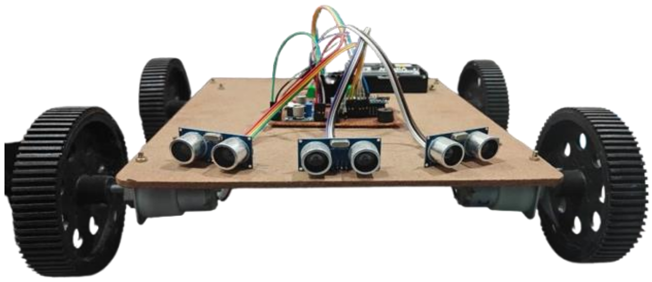
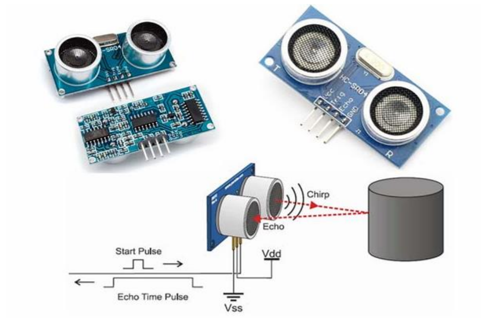
of input, control, output, communication, and power units. Each module performs a specific function, ensuring efficient coordination and reliable system performance.



2. Hardware Design

Sensor Configuration



The system employs three ultrasonic sensors positioned at the front of the vehicle to detect obstacles in multiple directions. The sensors are arranged to cover left, center, and right regions, thereby improving detection accuracy and minimizing blind spots. Each sensor continuously measures the distance to nearby objects using ultrasonic wave propagation and echo detection principles.

Microcontroller Unit

An embedded microcontroller is used as the central processing unit to manage system operations. It receives input signals from the ultrasonic sensors, processes the data, and generates control signals based on predefined conditions. The microcontroller ensures real-time processing and effective coordination between all system components.

Motor Driver Integration

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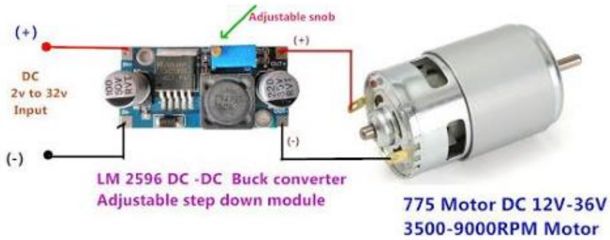
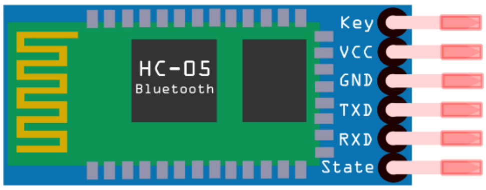
A motor driver module is incorporated to control the speed and direction of the DC motors. It acts as an interface between the microcontroller and the motors, enabling precise control of motion. The motor driver facilitates gradual speed reduction and complete stopping of the vehicle when an obstacle is detected within a critical range.

Power Supply System



The system is powered by a battery source, and a voltage regulation unit is used to provide stable and controlled power to all electronic components. This ensures consistent system operation and protects sensitive components from voltage fluctuations.

Wireless Communication Module



A Bluetooth communication module is integrated into the system to enable wireless interaction with a mobile device. This feature allows real-time monitoring and enhances system usability by providing an interface for user control and data observation.

Warning System

A buzzer is incorporated as an alert mechanism to notify the user when an obstacle is detected within a certain range. This provides an early warning before the braking action is applied, improving overall safety.

Circuit Design

The circuit design involves proper interconnection of all hardware components. The ultrasonic sensors are connected to the microcontroller through digital input-output pins, while the motor driver is interfaced with output pins for motor control. The Bluetooth module communicates via serial interface, and the power supply is regulated before distribution to all modules. Proper grounding and wiring practices are maintained to ensure stable and noise-free operation.

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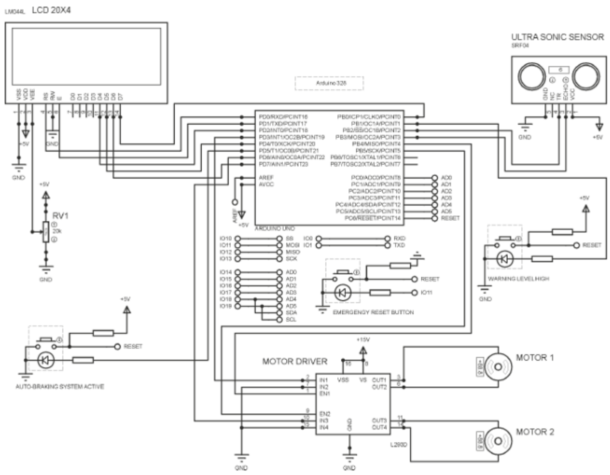

Software Implementation

The system is programmed using an embedded development environment. The software is responsible for sensor interfacing, data processing, decision-making, and control of the motor driver. The program continuously reads sensor inputs, calculates distances, and executes control logic based on predefined thresholds.

The software also manages the activation of the buzzer and handles communication with the Bluetooth module for monitoring and control purposes.

Algorithm Implementation

The implemented algorithm follows a continuous loop of sensing, processing, and action. The system evaluates sensor data in real time and determines the appropriate response. The algorithm ensures that the braking action is applied progressively, avoiding sudden stops and ensuring system stability.

Prototype Development

The system is implemented as a compact prototype mounted on a mobile platform. All components, including sensors, microcontroller, motor driver, and power supply, are arranged efficiently to ensure proper functionality. The prototype demonstrates real-time obstacle detection and automatic braking under various test conditions.

Implementation Challenges

During the development of the system, several challenges were encountered, including sensor calibration for accurate distance measurement, interference between multiple sensors, power management issues, and synchronization of system components. These challenges were addressed through proper design adjustments and testing.

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V. RESULTS AND DISCUSSION

1. Experimental Setup

The developed automatic braking system was implemented as a prototype model and tested under controlled conditions to evaluate its performance. Obstacles were placed at varying distances in front of the system, and the response of the sensors, controller, and motor unit was observed. The system components, including ultrasonic sensors, microcontroller, motor driver, and communication module, were powered and operated under standard conditions.

2. System Performance

The system demonstrated effective performance in detecting obstacles and responding appropriately. The ultrasonic sensors successfully measured distances in real time, and the microcontroller processed the data with minimal delay. The motor driver responded accurately by adjusting motor speed based on the proximity of obstacles. The multi-sensor configuration improved detection coverage by enabling simultaneous monitoring of multiple directions. This reduced blind spots and enhanced the reliability of the system in dynamic environments.

3. Observed Results

The system behaviour was analyzed under different distance conditions:

- **Safe Range:** The system maintained normal operation with no interruption in motor movement.

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- **Moderate Range:** The buzzer was activated to provide an early warning, while the motor continued to operate with slight speed adjustment.
- **Critical Range:** The system reduced motor speed significantly, indicating the initiation of braking action.
- **Very Close Range:** The motor was completely stopped, demonstrating effective automatic braking.

This staged response ensured smooth and controlled braking, preventing abrupt system behaviour.

4. Performance Analysis

Obstacle Detection Accuracy
The use of multiple ultrasonic sensors significantly improved detection accuracy. The system was able to detect obstacles from different directions, ensuring comprehensive coverage.

Response Time
The system exhibited fast response to changes in distance. The delay between detection and braking was minimal, allowing timely action to prevent collisions.

Braking Efficiency
The gradual reduction in motor speed resulted in smooth braking performance. This approach minimized mechanical stress and improved overall system stability.

Reliability
The system operated consistently under repeated testing conditions. The integration of hardware and software components ensured stable and reliable performance.

The results confirm that the proposed automatic braking system effectively achieves real-time obstacle detection and automated control. Compared to conventional braking systems, the developed system reduces dependency on human intervention and improves reaction time. The integration of wireless communication further enhances system functionality by enabling monitoring and interaction. However, the system performance may be influenced by environmental factors such as surface properties and external noise, which can affect ultrasonic sensing. Overall, the proposed system demonstrates a practical and efficient solution for improving safety in small-scale vehicles and embedded applications.

VII.CONCLUSION

The present study successfully demonstrates the design and development of an advanced automatic braking system based on multi-ultrasonic sensor technology and embedded control. The proposed system effectively addresses the limitations of conventional braking mechanisms by introducing real-time obstacle detection and automated decision-making. The integration of multiple sensors enhances detection coverage and accuracy, enabling the system to monitor obstacles from different directions and reduce blind spots. The embedded microcontroller efficiently processes sensor data and executes control logic with minimal delay, ensuring timely response to potential collision scenarios. The motor driver interface enables smooth and controlled braking by regulating motor speed according to the proximity of obstacles. Additionally, the incorporation of a warning system improves user awareness, while the wireless communication module enhances system flexibility through remote monitoring and interaction. Experimental results confirm that the system performs reliably under various conditions, demonstrating fast response time, effective braking action, and stable operation. The proposed system provides a cost-effective and scalable solution for improving safety in autonomous vehicles, robotic platforms, and intelligent transportation systems. Overall, the work highlights the potential of integrating sensing technologies with embedded systems to develop efficient and intelligent safety mechanisms

VIII. FUTURE SCOPE

The proposed automatic braking system can be further enhanced by integrating advanced sensing technologies such as LiDAR, radar, and vision-based systems to improve detection accuracy and range. The incorporation of Artificial Intelligence and Machine Learning techniques can enable predictive decision-making and adaptive control in dynamic environments. Future improvements may also include integration with IoT for real-time communication between vehicles and infrastructure, as well as GPS-based tracking and emergency alert systems. Additionally, the system can be extended to interface with real vehicle braking mechanisms such as ABS for practical automotive applications. Overall, further optimization in power efficiency, system miniaturization, and user interface development can enable large-scale deployment in intelligent transportation **systems.**

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